FORAGE INTAKE AND DIGESTIBILITY BY GROWING BEEF CATTLE SUPPLEMENTED WITH CORN WHILE GRAZING NATIVE RANGE

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CHAPTER I

INTRODUCTION

In most countries of the world, grazing native range is an economical alternative for raising cattle without incurring high investment costs. Sixty five to seventy percent of beef is produced in temperate grasslands under grazing conditions (Reid and Jung, 1982, cited by Leaver, 1985). Production of livestock is usually limited at some time of the year by the quality and/or quantity of forage available to grazing animals. Supplementary feeding is an alternative to maintain or attain adequate gains per animal or hectare. Allden (1981) classified supplements into three groups: energy-rich, protein and those that provide inorganic nutrients which are generally utilized to correct nutritional disturbances commonly related to soil deficiencies.

Forage intake and utilization usually increase when small amounts of high protein supplement are fed to cattle grazing low quality forage (Horn and McCollum, 1987; Wallace, 1988). Supplement conversion ratios of 3 to 4:1 are common when protein supplements are fed (McCollum and Horn, 1990). Energy supplements usually have a conversion ratio greater than 8:1. Animal performance may respond differently to energy supplements depending on factors such as level of supplementation, pasture quality, season of the year, time of day and method of grain processing among others. Allison (1985) stated that type and amount of supplement combined with forage availability and grazing intensity were the major management-controlled variables affecting intake of ruminants.

The objective of this research was to evaluate the influence of different levels of a corn-based energy supplement on forage and nutrient digestibility and intake, by growing cattle grazing native range in late spring and summer.

CHAPTER II

LITERATURE REVIEW

EFFECT OF SUPPLEMENTATION ON INTAKE AND DIGESTIBILITY

Type and Processing of Energy Concentrates

The source of grain can have a great influence on digestibility. Digestion of starch from corn and sorghum grain is considerably lower than from other grain sources, possibly due to structural differences in the starch stored in the grain (Orskov et al., 1969). The extent of digestion of sorghum in the rumen and total tract is lower than corn when processed in similar manner (Owens et al., 1986; Waldo, 1973).

Maxson et al. (1973) reported that the net energy of bird resistant sorghum was considerably less than regular sorghum grains. Vanzant et al. (1990) compared three types of grain (sorghum, wheat and corn) fed at .37% of BW to steers grazing bluestem range early in the growing season. The sorghum and corn diets contained soybean meal making them isonitrogenous with the wheat supplement. Forage intake and DM digestion of the total diet were unaffected by supplementation or type of supplement. Brake et al. (1989) conducted an experiment in which steers were fed two different forages (orchardgrass and bermudagrass) alone or with supplemental ground corn (.6% BW) or barley (.64% BW). Total OMD was higher for bermudagrass than for orchardgrass when the steers were fed grain. Total DMI was higher with grain. Barley-supplemented steers consumed more DM than the corn group. This suggested that barley improved nitrogen status of the animal more than corn.

Fredrickson et al. (1991) fed prairie hay alone or supplemented with four different grains (barley, corn, sorghum and wheat) to provide .25% starch in the total diet of steers. Hay intake was unaffected compared to controls while total OM digestibility and OM intake were increased.

In general, grinding, rolling or flaking of grains increases digestibility while pelleting has little effect (Church, 1976). Ruminal starch digestion is increased by processing (Owens et al., 1986). Adeeb et al. (1971) reported that total tract digestion was generally increased by processing and reducing particle size. These benefits of processing generally are greater with corn and sorghum than with other grains (McNeil, 1971). Ruminal production of volatile fatty acids was measured in steers fed corn grain in whole or ground form (Sharp et al., 1982). The ruminal concentration of propionate was reduced and butyrate was enhanced with whole compared to ground corn diets. The conversion of acetate to butyrate was about 70% greater with whole than with ground grain. Moe and Tyrell (1977) found that in timothy hay diets the digestibility of the corn was positively associated with the fineness of grind.

Digestibility was increased by 10 units compared with whole corn. Decreasing particle size of corn grain improved the digestibility of the cell-soluble portion of the diet. On the other hand, finely ground corn can be detrimental to the roughage portion of the diet (Orskov, 1976).

Orskov et al. (1974b) fed lambs four different grains (barley, corn, wheat and oats) processed three ways (whole grain, pelleted whole or pelleted rolled). In general, forage digestibility was not greatly affected by processing. When whole rather than processed grain was fed, rumen pH and fermentation patterns were more stable. At one extreme, whole oats produced a VFA profile similar to that of a roughage fermentation while pelleted wheat and corn resulted in greater proportions of propionic acid. Subsequent studies reported similar results (Orskov et al., 1974a,b).

Fraser and Orskov (1974) compared rolled and whole barley (both pelleted) and found that digestibility of the unprocessed barley was higher than that of the processed barley. Feed intake by lambs was not affected.

Goetsch et al. (1986) fed two forms of corn (whole and ground) with different roughage sources (chopped alfalfa, cottonseed hulls or chopped prairie hay) in high concentrate diets. Ruminal pH was higher for whole corn diets at 2 and 6 hours postfeeding. Grinding probably increased energy availability immediately after the meal, increased ammonia utilization and lowered the pH. These observations suggest that feeding corn in whole rather than ground form will decrease dietary crude protein requirements.

Hannah et al. (1989) conducted two experiments with cattle grazing tall fescue. In the first trial, cattle were supplemented with whole or ground pelleted corn at 1% BW weight or were unsupplemented. Total OM intake was higher for supplemented animals. Although forage OM digestibility was higher for the unsupplemented group, forage intake was similar between treatments. Grazing time was reduced for the animals supplemented with whole corn. No differences were found between ground corn and the other two treatments. In another trial, no supplement and ground-pelleted corn or dry corn gluten feed (CGF) fed at 1% BW were compared. Total OM intake was lower and grazing time was higher for the unsupplemental cattle. In another study, Meijs (1986) found that the mean substitution rate of forage by concentrate was reduced when high fiber concentrates were fed to dairy cows instead of high starch concentrates while grazing high quality forage (perennial ryegrass). Similar results were reported by Thomas et al. (1984).

Digestibility of ADF was reduced when dried grass was supplemented with high levels of barley (Lonsdale et al., 1971; Orskov and Fraser, 1975). Orskov and Fraser (1975) reported an increase in total feed intake by lambs when the hay diet was supplemented with low (25 g/k $BW^{.75}$) versus high levels (50 g/k $BW^{.75}$) of pelleted barley. The reduction was higher for pelleted barley than for whole grain.

Level of Supplementation

Most of the experiments that relate energy supplementation with forage or hay intake were carried out with low quality roughages or forages. Several authors have reported that intake and digestibility of low quality roughages are depressed by energy supplementation (Chase et al, 1985b; Fleck et al., 1987; Lusby and Wagner, 1986; Elliot, 1967; Sanson and Clanton, 1989). Chase and Hibberd (1985b, 1987) fed four levels of corn (0, .9, 1.8, and 2.7 kg/d) to cows consuming prairie hay ad libitum. Hay intake and digestibility were depressed at supplement levels higher than .9 kg/d. Total DMD remained constant. This indicated that the corn substituted for the hay at corn intake greater than .9 kg/d.

Pordomingo et al. (1991) reported that forage OM intake by steers grazing shortgrass prairie decreased linearly (P =.02) when level of supplemental corn was fed in excess of .2% BW. Forage intake tended to increase when the steers were fed .2 % BW. Total feed intake was not affected by level of corn supplementation. Total DMI and ADG increased when steers fed timothy-fescue hay were supplemented with high levels of barley (1% BW), but no differences were noted at a lower level (.5% BW) of supplementation (Forbes et al., 1967). Forage intake declined with increasing supplement intake. Jones et al. (1988) compared digestion and intake in steers fed bermudagrass (warm-season) or orchardgrass (cool-season) and supplemented with 0 or .5% BW of corn. Daily DMI was depressed by supplement (2.30 vs 2.56) while total OM digestion was improved with the supplement.

In contrast, Kartchner (1981) found no difference between forage DMI, forage DMD, total DMI and total DMD when cows grazing native range in the fall and winter were supplemented with cracked barley or cottonseed meal or received no supplement. In a second trial, forage DMI by cows was similar for the unsupplemented treatment and the barley supplement, but forage digestibility was lower for the barley supplement than the control. The authors concluded that differences between years were probably due to the mild weather conditions in the first year and unlimited forage availability.

Campbell et al. (1969) observed a linear ($P<.01$) depression of CP and CF digestibility in sheep that were grazing kikuyu grass and supplemented with increasing amounts of cracked corn. But, the digestibility of OM, EE, NFE and energy in the total ration were improved.

Sanson and Clanton (1989) concluded that as whole shelled corn intake increased, hay DMI decreased although total DMD increased and hay DMD remained constant. Similar results were reported by Sanson et al. (1990), however, hay DMD was improved with supplementation. In this trial, protein content of the diet was 0.73 g/kg BW for all the treatments.

Supplemental energy intake above 0.041 Mcal per kg BW, depressed forage intake without influencing forage DMD in cattle grazing Nebraska rangeland (Rittenhouse et al., 1970). Total DMI and DMD increased as level of supplementation increased.

Goetsch et al. (1991) compiled the data of several recent trials with steers fed bermudagrass hay and supplemented with corn. The authors concluded that for each kg of corn, bermudagrass intake decreased .46 kg, but total OMD increased while hay digestibility was depressed.

Scales et al. (1974) carried out an experiment to evaluate the response in liveweight gain of calves that were supplemented with different levels of protein and energy while grazing sandhill range in the winter. Calves fed the energy supplement (510 g of corn) or no supplement were lighter than the animals fed increasing levels of protein. Compensatory growth was observed in both treatments (non-supplemented and energy supplement), but the rate of growth was not sufficient in the case of non-supplemented animals to reach the weight of the high protein treatment.

Hennessy et al. (1983) reported that hay intake was reduced when steers weighing 142 kg were fed 560 or 1120 g/hd/d of sorghum grain. Steers fed the high level of supplement maintained weight while animals in the low and non-supplemented treatments lost weight.

Coleman et al. (1976) found that ADG increased when steers grazing St. Augustine grass were fed (4.1 to 4.5 kg/d) a supplement containing approximately 15% CP and 2.9 ME/kg. Forage intake and digestibility were not measured. Similarly, weight gain by yearling steers grazing irrigated pastures and consuming 0, .23, .45, .91 and 1.82 kg ground yellow corn/d increased linearly with level of grain (Lake et al., 1974a). In a 3 year study, the effect of feeding 5 levels of energy supplement to steers during the spring grazing season was evaluated (Denham, 1977). Steers in all supplement treatments gained more weight than unsupplemented cattle.

In a 5 year study on a semi-desert range in Nevada, cows were fed no supplement, .45 kg of barley, .45 kg of soybean meal or cottonseed meal or 1.36 kg of alfalfa. All supplementation treatments maintained BW during the winter while the control animals lost .09 kg/d. The barley and alfalfa treatments improved the number of calves weaned while animals consuming barley were heavier than others (Speth et al. 1962).

Pasture Quality

One of the problems of native range is the quality and/or quantity of the pastures available to the animal. Warm-season perennial grasses generally lack the necessary quality for young calves to gain at a desirable rate. Forage intake is limited by rumen capacity and bulky feedstuffs may not be consumed in sufficient amounts to meet maintenance and gain requirements (Balch and Campling, 1962; Ellis, 1978; Grovum, 1986; Mc Donald et al., 1988).

Horn and McCollum (1987) summarized several experiments and analyzed the effect of increasing amounts of high starch energy supplements on voluntary intake (cattle and sheep) of forages of different DMD. The substitution ratios increased as forage DMD increased (r=-.93 for cattle, r=-.87 for sheep). When forage DMD was below 55% little or no substitution was noted. It was concluded that, in general, appears that concentrates can be fed up to 30 g/kg MBW without substituting for forage intake.

Reduction in roughage intake associated with concentrates seems to be more clear for high quality than for low quality roughages (Holmes and Jones, 1964).

When energy supplements were fed to animals grazing low quality forage, the conversion factor ranged from 5 to 8 (kg of supplement/kg of additional gain) with an average of 6.9 (Coleman, 1977). This resulted in additional DE intake rather than complete substitution of concentrate for forage. The efficiency of conversion of the energy supplement was reduced when animals grazed relatively high quality forage, indicating that the supplemental feed replaced forage at a greater rate (Coleman, 1977). In studies by Lake et al. (1974b) and Coleman et al. (1976), the efficiency of supplement utilization decreased as the level of grain increased, suggesting that the substitution rate was higher at high levels of supplementation. In another study by Lake et al. (1974a), total DMI by steers grazing irrigated pastures and supplemented with corn was not affected, but supplemental corn reduced forage intake in a ratio of 1:1 ($P < .05$).

When cattle grazed high quality pasture, concentrate substituted for forage, daily gain increased only slightly, and supplement conversion was poor (Lowrey, 1976). Umoh and Holmes (1974) found no difference in liveweight gain and total intake between control animals and those fed barley straw, cane molasses or molasses sugar-beet pulp while grazing a mixed pasture of perennial ryegrass and white clover. On the other hand, Hodgson and Tayler (1972) improved weight gains of steer calves grazing perennial ryegrass at a high grazing intensity by feeding barley. They also observed an increase in stocking rate and live weight gain per ha of 36% and 63%, respectively, over the unsupplemented group.

Bellows and Thomas (1976) carried out an experiment to assess the effects of energy supplements on reproductive performance of lactating beef cows grazing western wheatgrass. Weight changes of the cows or calves were not affected but reproductive performance of unsupplemented cows tended to be higher than that of cows receiving higher levels of energy supplement. Cows were apparently using the grain as a substitute for the wheatgrass rather than a supplement.

Meijs and Hoekstra (1984) found that the substitution rate for starchy concentrates depends on forage allowance. A curvilinear relationship between forage intake and forage allowance was reported by Greenhalgh et al. (1966). Newton and Young (1974) compared 3 stocking rates for lambs on perennial ryegrass pasture. Substitution rates were elevated at high forage allowance. Similar results were reported by Leaver et al. (1968) and Allden (1981).

Time and Frequency of Supplementation

Knowledge of livestock behavior can be a tool for feeding supplements without interfering with the hours in which cattle are grazing.

Adams (1985) compared two feeding times (0730 vs 1330h) and two treatments, .3 kg corn per 100 kg BW versus no supplementation while grazing Russian wild ryegrass in the fall. Forage intake was greater for the unsupplemented steers than for the average of the supplemented groups. But intake was higher for the cattle fed in the afternoon compared to those fed in the morning. Energy intake, digestibility and ADG were higher for the steers supplemented in the afternoon than for those fed in the morning. Total DMI was not different for the control treatment versus the average of the steers fed supplements, but steers fed in the afternoon had higher total intakes than those fed in the morning. Steers that were supplemented did not graze for a period of 2 to 4 hours following supplementation. Adams (1985) concluded that the disruption of normal grazing activity by feeding supplements can affect performance and forage intake of steers grazing in fall. Goetsch and Owens (1984) also reported that DMD tended to be higher when cattle were fed at 2 PM than when they were fed at 8 AM with three different supplements (rolled corn, ground alfalfa or soybean meal).

Chase and Hibberd (1985a) fed two levels of corn (.82 or 1.73 kg/day) every day or alternate days. The frequency of feeding did not influence hay or DM intake, but tended to depress hay and DMD. These workers concluded that the depression in DOMI was not large enough to justify the added expense of daily supplementation. Adams (1986) reported that the gains of cattle fed grain supplements daily were double those fed alternate days for a ten-week period during winter. These results do not agree with those from protein supplementation trials with feeding 1 to 3 times weekly (Pearson and Whitaker, 1972; Mc Ilvain and Shoop, 1962; Melton and Riggs, 1964; Hennessy et al., 1981).

Time of the day at which animals are feed seems to be an important factor that could increase total dry matter digestibility and therefore performance of the animals. Energy supplementation when quality and/or quantity is lacking could be a good buffer to maintain carrying capacity of rangelands.

MEASUREMENTS OF DIGESTIBILITY AND INTAKE

Use of Markers

Apparent digestibility of the diet can be measured by conventional digestion trials or by the calculation of the digestibility of a feedstuff by difference (Merchen, 1988). These procedures are very tedious and sometimes impractical due to the fact that they require the total collection of feces to determine the apparent digestibility of a known diet. In grazing studies, estimation of forage digestibility and intake are necessary for an adequate understanding of the nutrient status and behavior of the animals. The use of markers is an important methodology for these purposes.

Markers can be divided into two types - internal and external markers. Internal markers are defined as natural constituents of the plant that are neither digested nor absorbed by the animal. External markers must have the same characteristics as internal markers, but they are administered orally or intraruminally to the animal (Pond et al., 1985; Cochran et al., 1986; Cochran et al., 1987; Merchen, 1988). Cordova et al. (1978) stated that internal markers are more frequently used to estimate digestibility, while external markers are more commonly used for estimating fecal output.

Kotb and Luckey (1972) described the characteristics of an "ideal" marker. They include: (1) inert with no toxic physiological or psychological effects; (2) neither absorbed nor metabolized within the gastrointestinal (GI) tract; (3) have no appreciable bulk; (4) mix intimately with and remain uniformly distributed in the digesta; (5) have no influence on GI secretion, digestion, absorption, or normal motility; (6) have no influence on the microflora of the GI tract; (7) have physico-chemical properties, readily discernible throughout the GI tract, which allow ready, precise, quantitative measurement. Merchen (1988), Cochran et al. (1986) and MacRae (1974) stated that many materials utilized as markers do not fulfill all of these criteria, but many are adequate to provide meaningful data.

Internal markers

Several markers have been used to estimate digestibility. Galyean et al. (1986) categorized them as older methods and newer methods. The former includes the use of lignin, chromagen or silica. Several authors have reported problems in the recovery of these markers (Kotb and Luckey, 1972; Wallace and Van Dyne, 1970; Van Soest, 1982; Fahey and Jung, 1983; Scales et al., 1974). The newer methods commonly include indigestible acid detergent fiber (IADF) (Penning and Johnson, 1983; Nelson et al., 1990) and indigestible neutral detergent fiber (INDF) (Lippke et al., 1986; Berger et al., 1979) and acid insoluble ash (AIA) (Thonney et al., 1985; Thonney et al., 1979; Porter and Sniffen, 1985; Van Keulen and Young, 1977).

Krysl et al. (1988) found no differences in DMD estimates (P>.05) with three different markers (IADF, INDF, and acid detergent lignin (ADL)) when animals were fed four different diets. Hunt et al. (1984) reported similar results with estimates based on ADL and ADF, but AIA overestimated DMD compared with total collection. Cochran et al. (1987) stated that accuracy of IADF to estimate digestibility varies with type of diet from that of total collection. In recent research (Judkins et al., 1989), the digestibility of six diets was estimated by eleven different techniques. The authors concluded that no single technique provided accurate estimates across all diets and feeding conditions.

External markers

External markers are frequently used to estimate fecal output, and in combination with digestibility of the diet, calculate voluntary intake by the animal (Pond et al., 1987).

Stained feeds was the first method used to obtain digesta retention time; this is a tedious method and subject to human error (Merchen, 1988). Other common markers that are used are rare-earth elements such as cerium (Ce), lanthanum (La), samarium (Sm), ytterbium (Yb), and dysprosium (Dy). All of these have strong adsorptive properties (Pond et al., 1987). Chromium-mordanted fiber results in the formation of complex between chromium and plant cell walls and is indigestible when the mordant is greater than 8% (Ellis et al., 1982).

Chromic oxide is an insoluble metal used for measuring digestibility and digesta flow (Merchen, 1988). The primary problem with chromic oxide is the wide variation in fecal recovery, mainly due to diurnal variation in its excretion (Hardison and Reid, 1953; MacRae, 1974; Ellis et al., 1982). However, Prigge et al. (1981) found no difference in fecal output estimate due to one vs twice daily grab sampling. In general, the literature shows that it is better to sample more times in the day rather than increasing dosing frequency (Prigge et al., 1981; Musimba et al., 1987).

Galyean et al.(1986) suggested that a minimum of four days of fecal collection is required, while Pond et al.(1987) stated that the marker must be administered for at least five days prior to sampling.

Even though losses in fecal recovery of markers can be expected under grazing conditions, total fecal collection can be difficult and impractical, therefore the use of markers is an excellent tool to estimate digestibility and intake.

CHAPTER III

FORAGE INTAKE AND DIGESTIBILITY BY GROWING BEEF CATTLE CALVES SUPPLEMENTED WITH CORN WHILE GRAZING NATIVE RANGE

Abstract

Trials were conducted in June and August of 1990 to evaluate the effects of corn supplementation on intake and digestibility measurements in calves grazing on tallgrass prairie. Thirty beef calves (avg. wt. 197 kg in May and 237 in August) were blocked by sex and weight and randomly assigned to five supplement treatments - 0, .2, .4, .6 and .8% BW/d of pelleted ground corn. The calves grazed freely with herbage allowances of 10 and 15 kg DM/100 kg BW/d in June and August, respectively. In June, forage OM intake (FOMI), total daily intake (TOMI), and total OMD (TOMD) increased linearly ($P<.01$) with supplement intake (SI). Forage OMD (FOMD) tended to increase linearly ($P<.18$). Based on regression coefficients, FOMI and TOMI increased .50 ($r^2=.17$; $s_{y \cdot x}=.33$) and 1.50 ($r^2=.65$; $s_{y \cdot x}=.33$) g/100 g BW for each 1 g/100 g BW SI, respectively. FOMD and TOMD were improved 7.18% ($r^2=.07$; $s_{y \cdot x}=7.61$) and 20.26% ($r^2=.53$; $s_{y \cdot x}=5.61$) for each 1 g/100 g BW SI, respectively. In

August, FOMI, TOMI and digestibility of each responded in a quadratic manner ($P<.01$). Derivative analyses of regression equations indicated that peak FOMI ($r^2=.37$; $s_{y \cdot x}=.34$) and FOMD ($r^2=.76$; $s_{y \cdot x}=7.92$) would occur at .27% and .25% BW SI, respectively, while peak TOMI ($r^2=.28$; $s_{y \cdot x}=.34$) and TOMD ($r^2=.53$; $s_{y \cdot x}=5.58$) would occur at .46% and .34% BW SI. Apparent CP digestibility (CPD) responded in a manner similar to TOMD; however, data suggest that impacts on CPD were more severe than on TOMD at high levels of SI. The results indicate that relatively high levels ($\leq$ 30g/kg MBW) of corn supplement can be fed without depressing forage intake by calves grazing on range in the summer. Hence, corn supplementation is a means of augmenting performance at a given stocking rate rather than depressing forage intake to allow for heavier stocking rates.
(Key Words: Growing cattle, Supplementation, Grazing, Intake, Digestibility).

Introduction

Feeding small quantities of high protein feedstuffs to calves grazing native range during late summer is a common practice. Protein supplements are an effective way to increase forage intake and digestibility (McCollum and Galyean, 1985; Guthrie and Wagner, 1988; McCollum and Horn, 1990; Del Curto et al., 1990). The response to energy supplements is less clear. In some conditions, forage intake and digestibility may decrease (Lusby and Wagner, 1986; Fleck et al., 1987; Elliot, 1967; Sanson and Clanton, 1989; Goetsch et al., 1991) while in others, little impact may occur (Vanzant et al., 1990).

Research with medium to high quality forages has shown that total DMI increases with energy supplementation (Forbes et al., 1967; Brake et al., 1989; Hannah et al., 1989). Pordomingo et al. (1991) reported that forage intake by steers grazing on shortgrass prairie was depressed when corn consumption was above .4% BW; whereas, forage intake tended to increase with .2% BW corn. Total DMI and digestion by steers consuming tallgrass prairie forage were not affected by level (0-.66% BW) of grain sorghum supplementation (Vanzant et al., 1990).

Meijs and Hoekstra (1984) reported that substitution of forage by concentrates depends on forage allowance. When concentrates were fed to animals with high levels of forage intake, the substitution rate was high, gains remained almost constant and feed conversion was low, while with low levels of forage intake, the substitution rate was low (Umoh and Holmes, 1974; Lowrey, 1976). Forbes (1986) suggested that supplementation can be justified to increase stocking rates, or whenever forage availability and/or digestibility are low.

The objective of this study was to determine the effect of energy supplementation on intake and digestibility measurements in steers grazing tallgrass prairie during the growing season.

MATERIALS AND METHODS

Study Area

The study was conducted on the Oklahoma Agricultural Experiment Station Research Range located approximately 20 km southwest of Stillwater, Oklahoma. Average annual precipitation measured in Stillwater is 831 mm, of which approximately 65% falls from April through September (Myers, 1982). Precipitation for 1990 was 950 mm and for the growing season 522 mm (NOAA, 1991; Appendix A). Average temperature during the growing season (May-August) is 24 C, with an average minimum of 18.5 C and an average maximum of 31.3 C (Appendix A). Average daily temperatures for the same period were 25 C.

Two pastures, 8.3 ha and 15.8 ha, were grazed in June and August, 1990, respectively. Forage standing crop was 1950 and 1400 kg/ha and herbage allowance was 10 and 15 kg/100 kg BW/d in June and August, respectively (Appendix B). The vegetation of the pastures was tallgrass prairie; predominant species were big bluestem (Andropogon gerardii), little bluestem (Schizachyrium scoparium), indiangrass (Sorghastrum nutans) and switchgrass (Panicum virgatum).

Field Trials

Trials were initiated on May 23 and July 25, 1990. Each trial included a 12 d adaptation period followed by a 5 d fecal sampling period. Thirty weaned fall-born beef calves (Angus and Hereford x Angus; approximate age = 8 months in may; average BW = 197 and 237 kg in June and August, respectively) were blocked by sex and weight and randomly assigned to five supplement treatments. Full weights were recorded on two consecutive days prior to each trial and three times during the feeding period.

The supplement treatments were: 0, .2, .4, .6 and .8% BW/d of a corn-based supplement (Table 1). The supplement was composed (as-fed basis) of 84% ground corn, 8% wheat middlings, 4.5% cottonseed hulls (CSH), 3% cane molasses and .5% limestone. All cattle within a supplement group were fed the same quantity of feed (g/d) based on the mean BW of 6 head in each treatment group (Table 2). All cattle grazed on a common pasture during the trials. Between 1000 and 1100 h daily, the cattle were gathered, put in feeding stalls and offered supplement (Table 1). After 1 h of access to the supplement, the cattle were returned to pasture and any refusals were weighed and the actual supplement consumption recorded. The animals had free access to a salt-mineral mixture that consisted of 50% salt, 49% dicalcium phosphate, .5% copper sulfate and .5% zinc oxide.

Chromium sesquioxide (Cr_2O_3) was administered once daily to allow estimation of fecal output. The supplemented animals were fed 100 g/d of a 1:9 Cr_2O_3:CSH mixture with the corn supplement. Consumption of the Cr_2O_3:CSH mixture by the unsupplemented group was erratic therefore 10g of Cr_2O_3 was administered orally in a gelatin capsule while the supplemented groups were in the stalls.

Fecal grab samples were collected twice daily (1100 and 1900 h) for 5 consecutive d, following an 8 d marker equilibration period. Samples were refrigerated until the end of the sampling period at which time they were composited within animal and lyophilized. Dry samples were ground through a 2 mm screen in a Wiley mill and stored in plastic bags.

At 1900 h on d 2 and 4 of each fecal collection period, masticate samples were collected from 4 steers fitted with an esophageal cannula. Samples were collected during a 45 min period. The samples were composited within steer for each trial, lyophilized, ground and stored in a manner similar to the fecal samples.

Laboratory Analyses

Masticate, supplement and fecal samples were analyzed for DM, ash and Kjeldahl N (AOAC, 1984), NDF and ADF (Goering and Van Soest, 1970), indigestible ADF (IADF; Krysl et al., 1988), starch (Galyean, 1990), and gross energy (GE). In addition, esophageal masticate samples were analyzed for in vitro organic matter digestibility (IVOMD, Galyean, 1990). Feces and the Cr_2O_3-CSH hulls mixture were analyzed for chromium (Williams et al., 1962). All data were calculated on an ash-free basis.

Total fecal output was estimated as the ratio of chromium intake to chromium concentration in the feces. Forage intake was determined by partitioning fecal IADF into forage and supplement IADF. The difference between total daily fecal IADF excretion and daily IADF consumption from the supplement was assumed to be fecal IADF of forage origin. Forage intake was estimated as the quotient of fecal forage IADF excretion and IADF concentration in the esophageal masticate. Digestibility was estimated by the ratios of fecal IADF and diet IADF (Penning and Johnson, 1983).

Statistical Analyses

Data were analyzed using the GLM procedure of the Statistical Analyses System (SAS, 1985). The initial model contained supplement level, block, trial, and supplement level X trial, in a randomized complete block design. A supplement level X trial interaction ($P<.01$) was noted for all data and the analysis was repeated within trial. Orthogonal polynomials were used to partition linear, quadratic, and cubic effects of supplement level. Data are reported as least square means. Observations for one animal were deleted from the August trial because intake estimates for the animal were in excess of 4.3% BW.

Regression equations were developed for each trial using GLM procedures. The independent variable - supplement intake - was expressed as actual consumption (g of supplement/100 g BW) by individual animals rather than as consumption based on mean BW of the treatment groups.

Results and Discussion

The chemical composition of the esophageal masticate is presented in Table 1. Chemical composition was relatively similar in June and August. Fiber, CP and IVOMD were similar to values reported for mid-June (Campbell, 1989) but in August, masticate samples were of higher quality than expected based on previous studies (Rao et al., 1973; Campbell, 1989). The unexpected higher quality in August may have been due to (1) lower than normal precipitation in June and July combined with cooler than normal temperatures in July (Appendix A), (2) higher forage availability (Appendix B) allowing greater selectivity in August, or (3) biased sampling of the fistulated steers. Drier, cooler growing conditions slows metabolic processes in forages and can maintain higher quality in the available forage (Van Soest, 1982). These conditions accompanied by 54 mm of rainfall the first week of August could account for higher quality forage on offer. Forage availability should not have limited intake in either trial (10% BW and 15% BW for June and August, respectively), but in August, animals had the opportunity for greater selectivity. Biased sampling is possible but would not be expected because the steers grazed a similar forage in an adjacent pasture between and during the sampling periods.

In June, forage OM intake (FOMI) increased in a linear manner (P<.03) with supplement intake while in August, a quadratic response (P<.01; Table 2) was observed but, FOMI was not depressed until supplement intake reached .8% BW (Table 2). Maximum FOMI occurred at the highest supplement level in June; FOMI increased .50 g/100g BW (Figure 1) for each 1 g/100g BW of supplement intake. The quadratic relationship in August resulted from normal or improved FOMI at supplement intakes of .2, .4, and .6% BW corn intake and a depression in FOMI at .8% BW. Derivative analysis of the quadratic equation (Figure 6) indicated that FOMI would peak when supplement was fed at .27% BW (Table 10). In a review, Horn and McCollum (1987) noted that energy supplements had very little effect on forage DMI when fed at less than 30g/kg MBW. In the present experiment, the maximum amount of corn (.8% BW) offered daily was 31.4 g/kg MBW (Table 2).

The common perception is that energy supplements will depress forage intake thereby allowing for heavier stocking rates or prolonged use of a marginal forage supply (Horn and McCollum, 1987). Instead, these results suggest that under these conditions corn can be supplemented at relatively high levels without depressing forage intake. Hence, this type of supplement would augment performance at a given stocking rate rather than depressing forage intake to allow increased stocking density or prolong the availability of a limited forage supply.

Forage DMI by steers consuming tallgrass prairie forage in the early summer was not affected as grain sorghum supplementation increased from 0 to .66% BW (Vanzant et al., 1990). Pordomingo et al. (1991) reported that FOMI by steers grazing shortgrass prairie in the summer tended to increase when corn was fed at .2% BW but FOMI was depressed at .4 and .6% BW corn intake. In another study with steers grazing on blue grama range in the summer, FOMI was improved when corn was fed at .16% of BW; no differences were observed between unsupplemented cattle and those fed .32% of BW corn (Branine and Galyean, 1985). Chase and Hibberd (1985b) fed corn and low protein prairie hay to cows and found no negative effect on FDMI until corn was supplemented at .48% BW.

Total OM intake (TOMI; Table 2) responded in a fashion similar to FOMI, increasing in a linear manner in June ($P<.01$; Figure 3) and a quadratic manner in August ($P<.01$; Figure 4). Due to the additive effect of corn intake, TOMI was improved 1.5 g/100g BW for each 1 g/100g BW supplement intake. In August, estimated peak TOMI occurred at .46 g/100g BW supplement intake. TOMI was similar for 0 and .8% BW supplement levels. These results agree with those of Hannah et al. (1989) who reported an increase in TOMI when animals were fed either whole or ground-pelleted corn at 1% BW. Rittenhouse et al. (1970), Sanson and Clanton (1989), and Vanzant et al. (1990) also noted a positive linear response in TOMI as supplemental concentrate increased.

Fecal output responded linearly in both trials (Table 2). These increases reflect the higher TOMI in June and the combined effect of higher TOMI and reduced forage digestibility in August (Table 3). Apparent forage OMD (FOMD; Table 3) in June tended to improve with level of corn supplement (P<.15; Figure 7). However, in August peak FOMD was estimated to accur at .25 g/100g BW supplement intake. FOMD was depressed at supplement intake in excess of .5 g/100g BW (Figure 8). Total OM digestibility (TOMD) reflected the response for TOMI (Table 3). In June, TOMD improved 2% for each .1% BW supplement intake (Figure 9). This can be explained by the lack of depression in FOMI and added consumption of a highly digestible supplement (P<.01). In contrast, the estimated peak TOMD in August occurred at .34% BW supplement intake (Tables 10).

Intake of digestible energy and OM reflected TOMI and TOMD responses (Tables 4 and 5; Figures 5 and 6). Elliot (1967) and Rittenhouse et al. (1970) found an increase in total digestible energy intake of the diet as energy supplementation was increased, even though forage intake was significantly depressed. Vanzant et al. (1990) also reported an increase in digestible energy intake as grain supplementation was increased, but forage intake was not depressed by the supplement. In the current study, DOMI increased 1.26 g/100g BW for each 1 g/100g BW supplement intake in June while in August, DOMI peaked at .4% BW supplement intake. In August, supplementation at .8% BW did not improve energy status (Table 4).

When N is not limiting for microbial growth, limited quantities of an energy supplement tend to stimulate OMD and passage rate, increase digesta flow and thereby increase forage intake (Branine and Galyean, 1985; Guthrie and Wagner, 1988). Elliot (1967) observed that at levels of protein intake in excess of 4 g/kg $BW^{.73}$/d, energy concentrates produced a small reduction in hay intake, therefore, total intake increased with amount of concentrate fed. At lower levels of protein intake, some evidence of curvilinear response to energy concentrate was observed. Lake et al. (1974a) reported higher weight gains by yearling steers when energy supplement intake was increased as long as protein content of the pasture was not limiting.

Forage CP content for both trials (Table 1) appeared to be adequate for the CP needs of the rumen microbial population. Diet CP never fell below 7%, a level suggested by Van Soest (1982) as minimal for the CP needs of rumen microbial population. Also, estimated CP intake was around 9 g/kg $BW^{.73}$ which is in excess of the 4 g/kg $BW^{.73}$ proposed by Elliot (1967).

Crude protein intake and CP digestibility (CPD) followed the same pattern as TOMI and TOMD for both trials (Tables 4 and 5). In June, CP intake increased linearly ($P<.01$), even at high levels of supplementation, due to a linear increment in forage intake and total intake, while fecal N (% OM) remained constant (Table 5) . In August, maximum CP intake and CPD were achieved at corn supplementation of .4% BW (Tables 4 and 5). Crude protein digestibility increased linearly (P<.01; Table 5 and 6) in trial 1, while in trial 2 CPD was depressed at high levels of supplementation (P<.01; Tables 5 and 9). Peak CPD occurred at .3 g/100g BW supplement intake (Table 10).

A parallel relationship between CP intake and TOMI was expected. However, the relationship between apparent TOMD and CPD would not necessarily be proportional because of independent factors affecting TOMD and CP accumulation in the feces. In fact, TOMD changed 6.4, 0, 22.4 and 1.2% with increasing supplement in June while CPD changed 27.31, -17.6, 9.0 and 0%. In August, TDOM changed 7.1, 13.1, -10.3 and -20.1 while CPD changed 13.9, 15.8, -24.6 and -40.3%. This suggests that the first increment of supplement disproportionately increased CPD compared to TDOM. On the other hand, the data suggest that supplementation had a disproportionately more severe negative impact on CPD at high levels of supplementation especially in August. This may indicate that protein content of the supplemental concentrate should be increased at feeding level near or above .8% BW.

Fiber intake and digestibility responded the same way as TOMI and TOMD (Tables 4 and 5) for both trials. Sanson et al. (1990) found that high levels of corn (.52% of BW) fed to steers on a low quality hay diet with adequate levels of protein depressed fiber digestion. Similar results were reported by Chase and Hibberd (1987) and Sanson and Clanton (1989).

Vanzant et al. (1990) found that NDF digestibility was unaffected by energy supplementation, while starch digestibility was depressed in a linear manner ($P<.01$) with increasing levels of sorghum grain in the diet. Joanning et al. (1981) also reported a depression in starch digestion as corn grain content was increased in the diet, but in their experiment the basal diet was corn silage that already had a high grain content and this depression was noted only at high levels of supplementation. On the other hand, Mertens and Loften (1980) suggested that starch does not affect fiber digestion by decreasing the potential extent of digestion, but rather by increasing digestion lag time.

In the present experiment the percentage of starch in corn was 64.8 (Table 1), therefore the higher amount of starch offered was .52% of BW. Fecal starch was not detectable except in the second trial when traces were noted with the high level of supplement. These results indicate starch digestibility was high, but did not affect fiber digestion for June and at least for the first three levels of supplementation in August. Goetsch and Owens (1987) suggested that limited amounts of corn may improve forage and nutrient utilization by increasing the amount of energy available for ruminal microbes. This would enhance protein flow to the small intestine and possibly stimulate forage intake.

The site of starch digestion cannot be determined from this study. The trend toward poorer apparent CP digestibility at high levels of supplementation in addition to the high apparent disappearance of starch suggests some starch was being digested in the large intestine at the higher supplementation levels. This would reduce the N supply recycled into the rumen by draining recycled N into the large intestine and sequestering it in microbial CP. This would require CP levels in supplements be increased at high levels of supplement intake.

IMPLICATIONS

These results suggest that supplementation may enhance daily gain of calves by increasing TOMI and TOMD. Under these conditions, stocking rate cannot be increased as a result of depressed forage intake by energy supplementation. Instead supplementation will augment energy intake at a given stocking rate therefore buffering energy intake and performance in situations where stocking rate depresses forage intake. Therefore, an increase in stocking rate without affecting daily gain and improved gain per hectare would be expected. Finally, it appears that in order to prolong the use of a limited forage supply, energy supplements must be fed in excess of .8% BW or 30 g/kg MBW.

TABLE 1. CHEMICAL COMPOSITION OF THE CORN-BASED SUPPLEMENT AND ESOPHAGEAL MASTICATES COLLECTED IN JUNE AND AUGUST.

ITEM	JUNE	AUGUST	SE[a]	SUPPLEMENT
OM, %	88.0	90.9	.59	92.0
	------------- % OM BASIS -------------			
CP	13.3	11.8	.40	9.7
NDF	76.9	76.3	1.25	----
ADF	40.5	38.2	.43	----
IADF	21.0	21.1	.50	2.0
IVOMD	54.5	55.0	.58	86.2
STARCH	-----	-----	-----	64.8
ENERGY, KCAL/G OM	4.9	5.3	.08	4.6

[a] N = 4.

TABLE 2. DAILY FORAGE INTAKE, DIET INTAKE AND FECAL OUTPUT BY CALVES GRAZING TALLGRASS PRAIRIE AND SUPPLEMENTED WITH DIFFERENT LEVELS OF CORN.

TRIAL	SUPPLEMENT INTAKE, g/100g BW 0.0	0.2	0.4	0.6	0.8	SE[a]	CONTRAST[b] ORDER	PROB
JUNE								
BODY WT, KG	197	197	197	197	195	4.8	L	.79
SUPPLEMENT, g/kg MBW	0	7.5	15.0	22.5	29.9			
DAILY INTAKE	----- g OM/100g BW -----							
FORAGE	1.65	1.42	1.77	1.82	1.89	.17	L	.03
TOTAL	1.65	1.62	2.17	2.41	2.69	.17	L	.01
FECAL OUTPUT	.90	.84	1.12	.95	1.06	.08	L	.03
AUGUST								
BODY WT, KG	236	239	236	237	237	6.7	L	.94
SUPPLEMENT, g/kg MBW	0	7.9	15.7	23.5	31.4			
DAILY INTAKE	----- g OM/100g BW -----							
FORAGE	1.90	2.01	2.21	1.88	1.31	.18	Q	.01
TOTAL	1.90	2.20	2.59	2.45	2.08	.18	Q	.01
FECAL OUTPUT	.90	.96	.94	1.06	1.13	.08	L	.01

[a] n = 6.
[b] L = Linear, Q = Quadratic.

TABLE 3. APPARENT DIET AND FORAGE DIGESTIBILITIES BY CALVES GRAZING TALLGRASS PRAIRIE AND SUPPLEMENTED WITH DIFFERENT LEVELS OF CORN.

TRIAL	SUPPLEMENT INTAKE, g/100g BW					SE[a]	CONTRAST[b]	
	0.0	0.2	0.4	0.6	0.8		ORDER	PROB
APPARENT DIGESTIBILITY								
JUNE	----------- % ----------							
FORAGE	45.4	43.1	40.1	50.3	48.5	4.34	L	.18
TOTAL	45.4	48.3	48.6	59.5	60.2	3.16	L	.01
AUGUST	----------- % ----------							
FORAGE	52.1	52.9	58.3	47.3	21.0	5.07	Q	.01
TOTAL	52.1	55.8	62.8	56.6	45.2	3.58	Q	.01

[a] n = 6.
[b] L = Linear, Q = Quadratic.

TABLE 4. DAILY INTAKE OF CP, NDF, DIGESTIBLE OM, GROSS ENERGY AND DIGESTIBLE ENERGY BY CALVES GRAZING TALLGRASS PRAIRIE AND SUPPLEMENTED WITH DIFFERENT LEVELS OF CORN.

TRIAL	SUPPLEMENT INTAKE, g/100g BW					SE[a]	CONTRAST[b]	
	0.0	0.2	0.4	0.6	0.8		ORDER	PROB
JUNE	--------- g/100g BW -------							
CP	.22	.21	.27	.30	.33	.02	L	.01
NDF	1.27	1.24	1.66	1.85	2.06	.13	L	.01
DOMI	.75	.78	1.05	1.46	1.63	.14	L	.01
	-------- Kcal/100g BW -----							
GE	7.33	7.19	9.63	10.71	11.96	.74	L	.01
DE	2.75	3.26	4.35	5.76	6.56	.62	L	.01
AUGUST	--------- g/100g BW -------							
CP	.25	.28	.33	.30	.25	.02	Q	.01
NDF	1.45	1.68	1.97	1.87	1.58	.14	Q	.01
DOMI	.99	1.24	1.65	1.39	.94	.17	Q	.01
	-------- Kcal/100g BW -----							
GE	8.92	10.30	12.07	11.38	9.56	.85	Q	.01
DE	3.96	5.20	7.12	5.57	3.98	.79	Q	.01

[a] n = 6.
[b] L = Linear, Q = Quadratic.

TABLE 5. APPARENT CP, NDF, ENERGY DIGESTIBILITIES AND FECAL N BY CALVES GRAZING TALLGRASS PRAIRIE AND SUPPLEMENTED WITH DIFFERENT LEVELS OF CORN.

TRIAL	SUPPLEMENT INTAKE, g/100g BW 0.0	0.2	0.4	0.6	0.8	SE[a]	CONTRAST[b] ORDER	PROB
JUNE	------------%------------							
FECAL N	3.24	3.13	3.24	3.30	3.28	.10	L	.31
APPARENT DIGESTIBILITY								
CP	16.5	21.0	17.3	32.8	33.0	5.02	L	.01
NDF	51.8	52.1	55.3	64.3	66.7	2.55	L	.01
ENERGY	37.2	45.3	45.2	53.8	54.9	3.92	L	.01
AUGUST								
FECAL N	2.81	2.73	2.90	2.91	2.75	.09	Q	.21
APPARENT DIGESTIBILITY								
CP	36.7	41.8	46.8	36.5	20.8	5.21	Q	.01
NDF	57.9	61.2	65.6	62.2	54.6	2.11	Q	.01
ENERGY	44.0	50.0	58.3	48.8	41.5	4.58	Q	.01

[a] n = 6.
[b] L = Linear, Q = Quadratic.

TABLE 6. REGRESSION RELATIONSHIPS AMONG CORN SUPPLEMENT INTAKE (G/100G BODY WEIGHT; X) AND DAILY INTAKE MEASUREMENTS AND FECAL OUTPUT (G/100G BODY WEIGHT; Y) FOR INDIVIDUAL CALVES GRAZING TALLGRASS PRAIRIE IN JUNE.

DEPENDENT VARIABLE	b_0	b_1	b_2	SY.X[a]	R^2	Pr>F
INTAKE						
CP	.20	.16	---	.04	.55	.01
NDF	1.16	1.15	---	.25	.64	.01
FECAL OUTPUT	.88	.25	---	.18	.15	.04
GE INTAKE, kcal/100 g BW						
	6.70	6.68	---	1.47	.65	.01

[a] N=30

TABLE 7. REGRESSION RELATIONSHIPS AMONG CORN SUPPLEMENT INTAKE (G/100G BODY WEIGHT; X) AND DAILY INTAKE MEASUREMENTS (G/100G BODY WEIGHT; Y) AND FECAL OUTPUT FOR INDIVIDUAL CALVES GRAZING TALLGRASS PRAIRIE IN AUGUST.

DEPENDENT VARIABLE	b_0	b_1	b_2	SY.X[a]	R^2	Pr>F
INTAKE						
CP	.25	.29	-.35	.05	.23	.03
NDF	1.41	1.86	-2.02	.26	.28	.01
FECAL OUTPUT	.87	.34	---	.13	.34	.01
GE INTAKE, kcal/100g BW						
	8.88	11.23	-12.45	1.62	.27	.14

[a] N=29

TABLE 8. REGRESSION RELATIONSHIPS AMONG CORN SUPPLEMENT INTAKE (G/100G BODY WEIGHT; X) AND DIGESTIBILITY MEASUREMENTS (%; Y) FOR CALVES GRAZING TALLGRASS PRAIRIE IN JUNE.

DEPENDENT VARIABLE	b_0	b_1	b_2	SY.X[a]	R^2	Pr>F
DIGESTIBILITY						
CP	15.1	22.71	---	8.95	.36	.01
NDF	49.8	20.60	---	4.52	.65	.01
GE	38.8	121.19	---	6.77	.47	.01

[a] N=30

TABLE 9. REGRESSION RELATIONSHIPS AMONG CORN SUPPLEMENT INTAKE (G/100G BODY WEIGHT; X) AND DIGESTIBILITY MEASUREMENTS (%; Y) FOR CALVES GRAZING TALLGRASS PRAIRIE IN AUGUST.

DEPENDENT VARIABLE	b_0	b_1	b_2	SY.X[a]	R^2	Pr>F
DIGESTIBILITY						
CP	35.9	62.56	-105.79	7.52	.62	.01
NDF	57.5	37.27	-52.12	3.44	.56	.01
GE	43.9	56.12	-76.77	7.14	.38	.01

[a] N=29

TABLE 10. PEAK INTAKE AND DIGESTIBILITY VALUES DETERMINED BY DERIVATIVE ANALYSES OF REGRESSION EQUATIONS (AUGUST).

DEPENDENT VARIABLE	SUPPLEMENT INTAKE (% BW)
FORAGE OM INTAKE, g/100g	.27
TOTAL OM INTAKE, g/100g	.46
DIGESTIBLE OM INTAKE, g/100g	.40
FORAGE OM DIGESTIBILITY, %	.25
TOTAL OM DIGESTIBILITY, %	.34
CRUDE PROTEIN DIGESTIBILITY, %	.30
NEUTRAL DETERGENT FIBER DIGESTIBILITY, %	.36

FIGURE 1. REGRESSION RELATIONSHIP BETWEEN CORN SUPPLEMENT INTAKE AND FORAGE DAILY INTAKE FOR CALVES GRAZING TALLGRASS PRAIRIE IN JUNE.

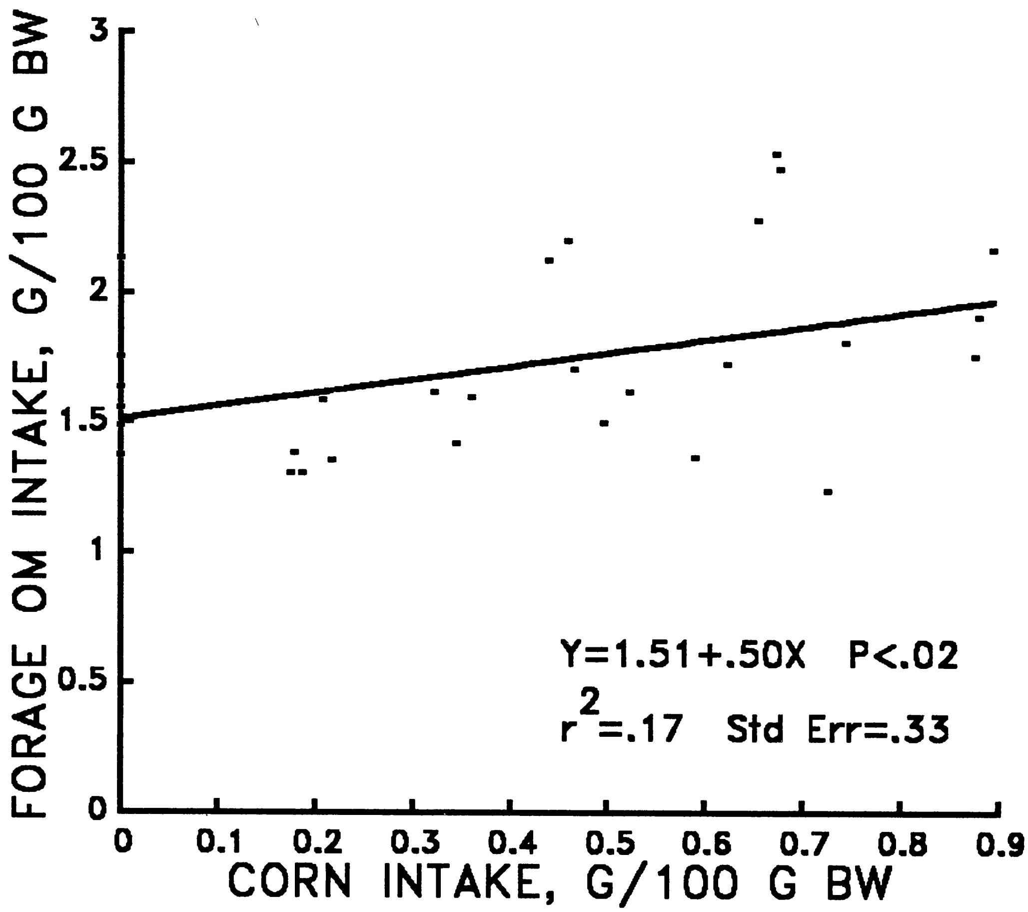


FIGURE 2. REGRESSION RELATIONSHIP BETWEEN CORN SUPPLEMENT INTAKE AND DAILY FORAGE INTAKE FOR CALVES GRAZING TALLGRASS PRAIRIE IN AUGUST.

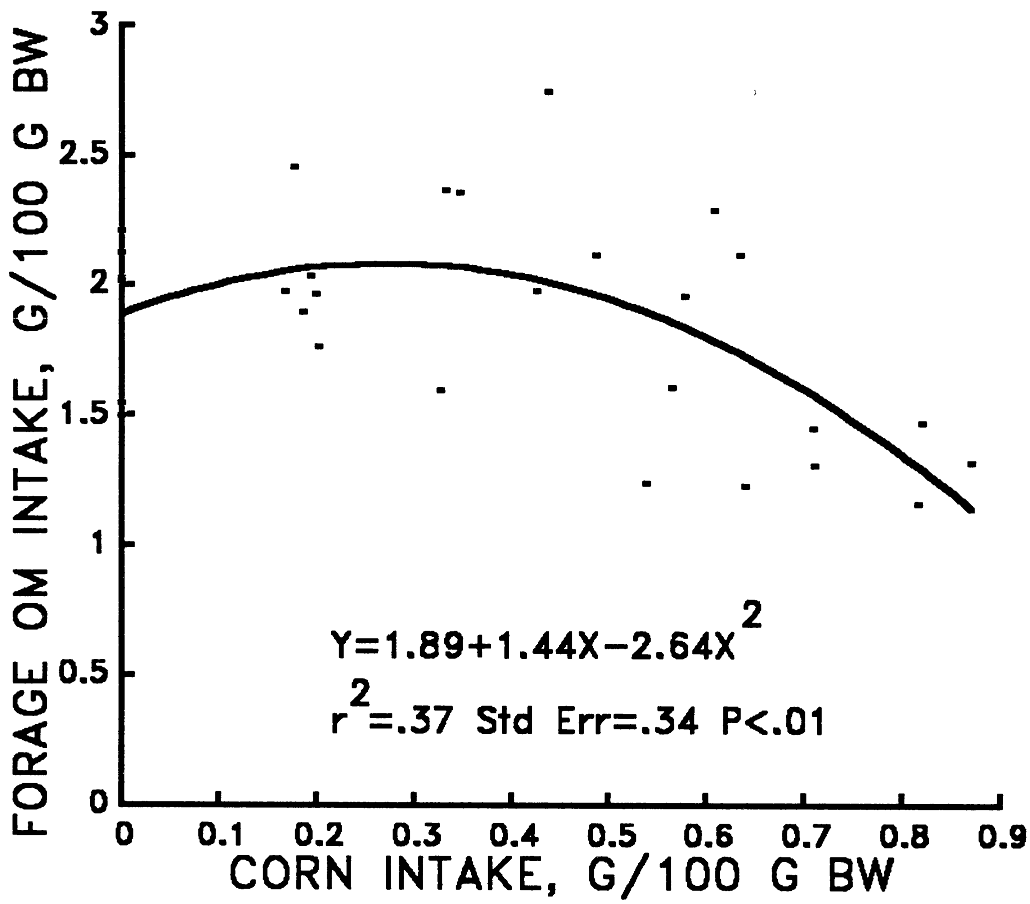


FIGURE 3. REGRESSION RELATIONSHIP BETWEEN CORN SUPPLEMENT INTAKE AND TOTAL DAILY INTAKE FOR CALVES GRAZING TALLGRASS PRAIRIE IN JUNE.

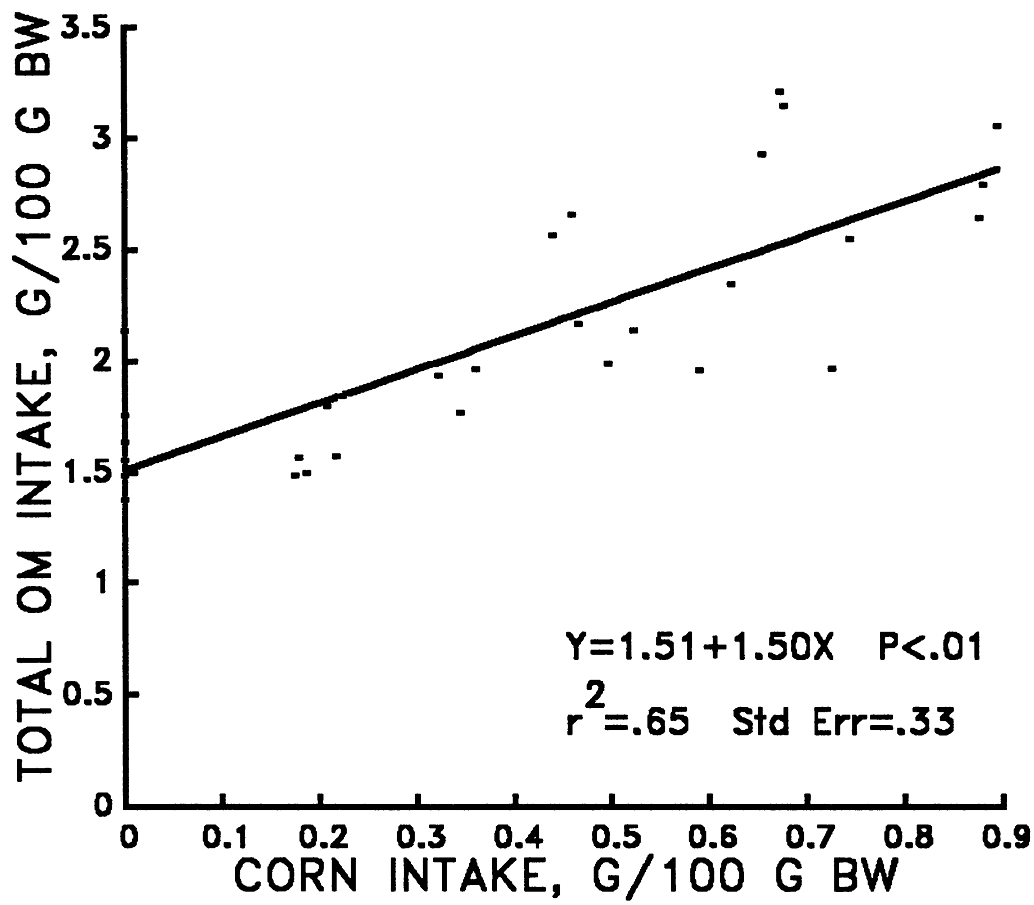


FIGURE 4. REGRESSION RELATIONSHIP BETWEEN CORN SUPPLEMENT INTAKE AND TOTAL DAILY INTAKE FOR CALVES GRAZING TALLGRASS PRAIRIE IN AUGUST.

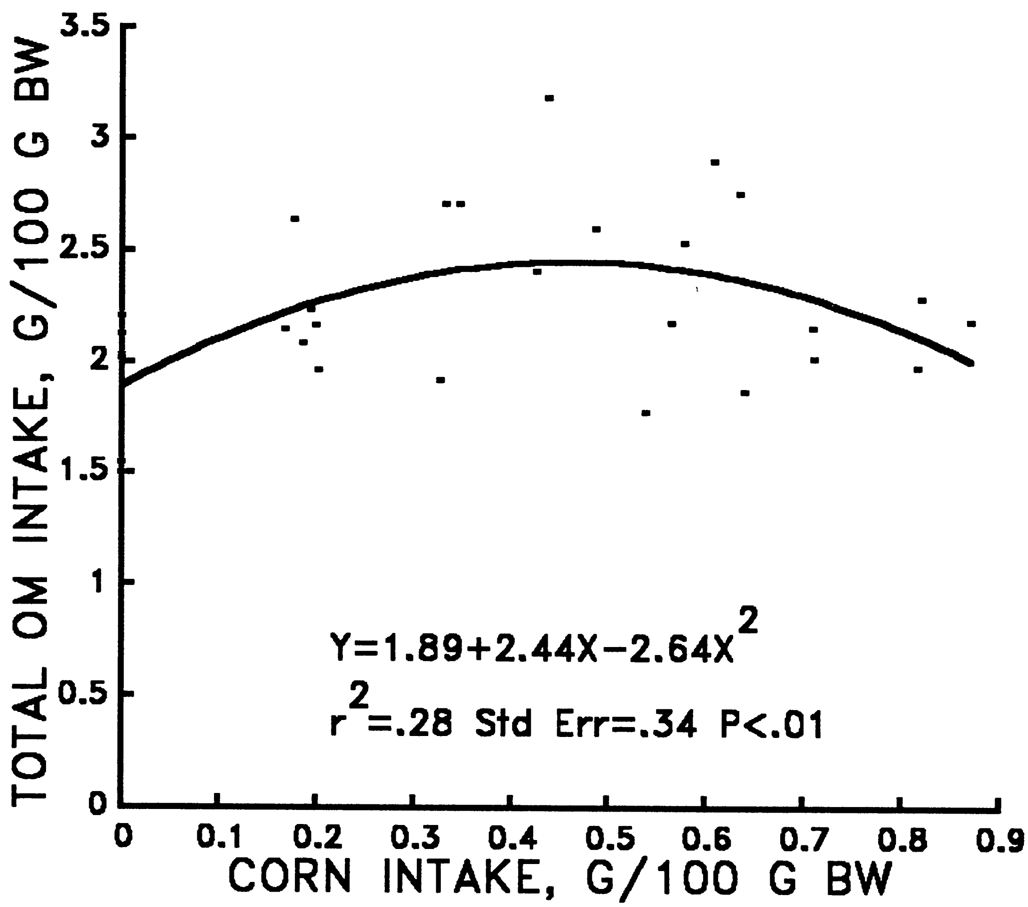


FIGURE 5. REGRESSION RELATIONSHIP BEWTEEN CORN SUPPLEMENT INTAKE AND DAILY DIGESTIBLE OM INTAKE FOR CALVES GRAZING TALLGRASS PRAIRIE IN JUNE.

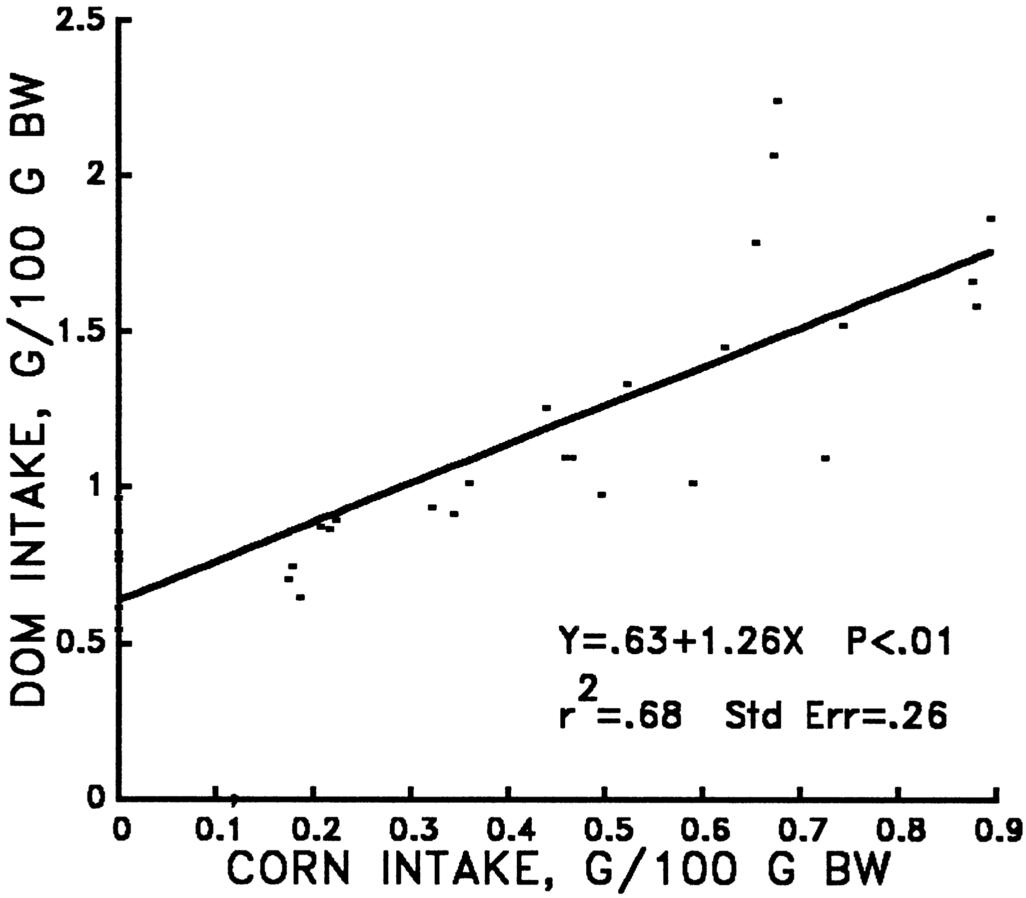


FIGURE 6. REGRESSION RELATIONSHIP BETWEEN CORN SUPPLEMENT INTAKE AND DIGESTIBLE OM DAILY INTAKE FOR CALVES GRAZING TALLGRASS PRAIRIE IN AUGUST.

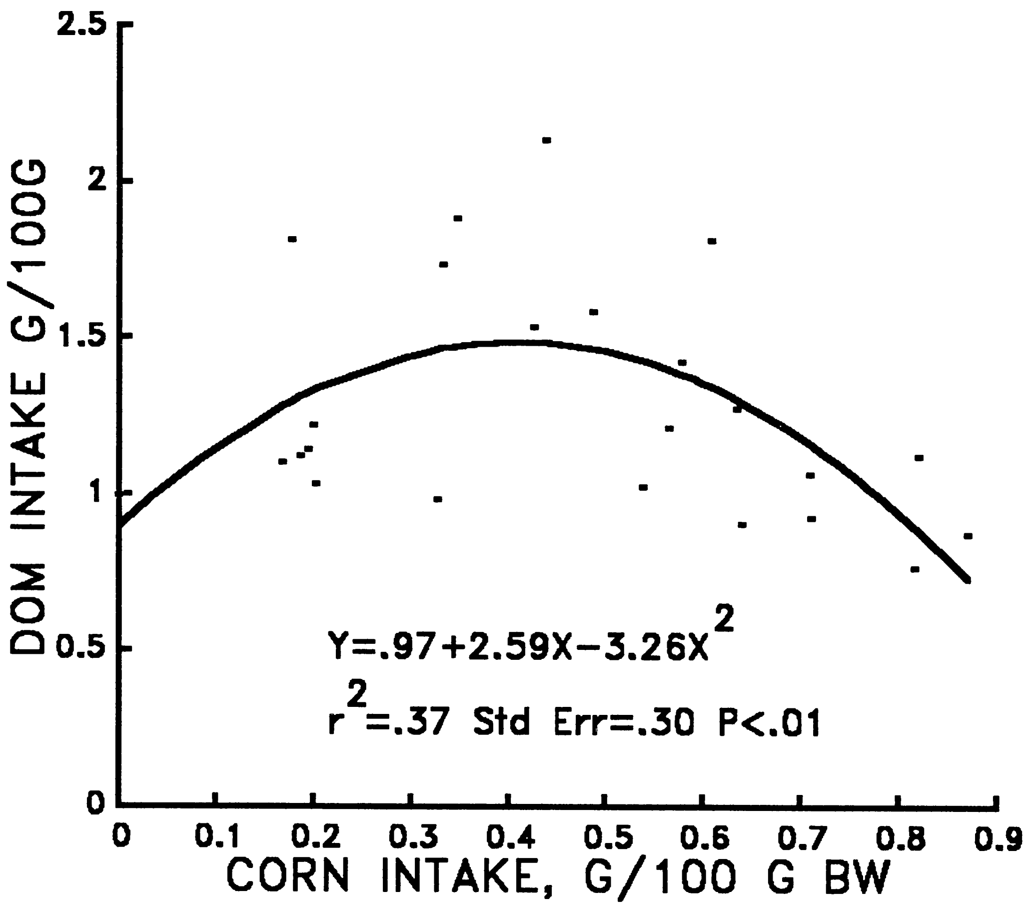


FIGURE 7. REGRESSION RELATIONSHIP BETWEEN CORN SUPPLEMENT INTAKE AND FORAGE DIGESTIBILITY FOR CALVES GRAZING TALLGRASS PRAIRIE IN JUNE.

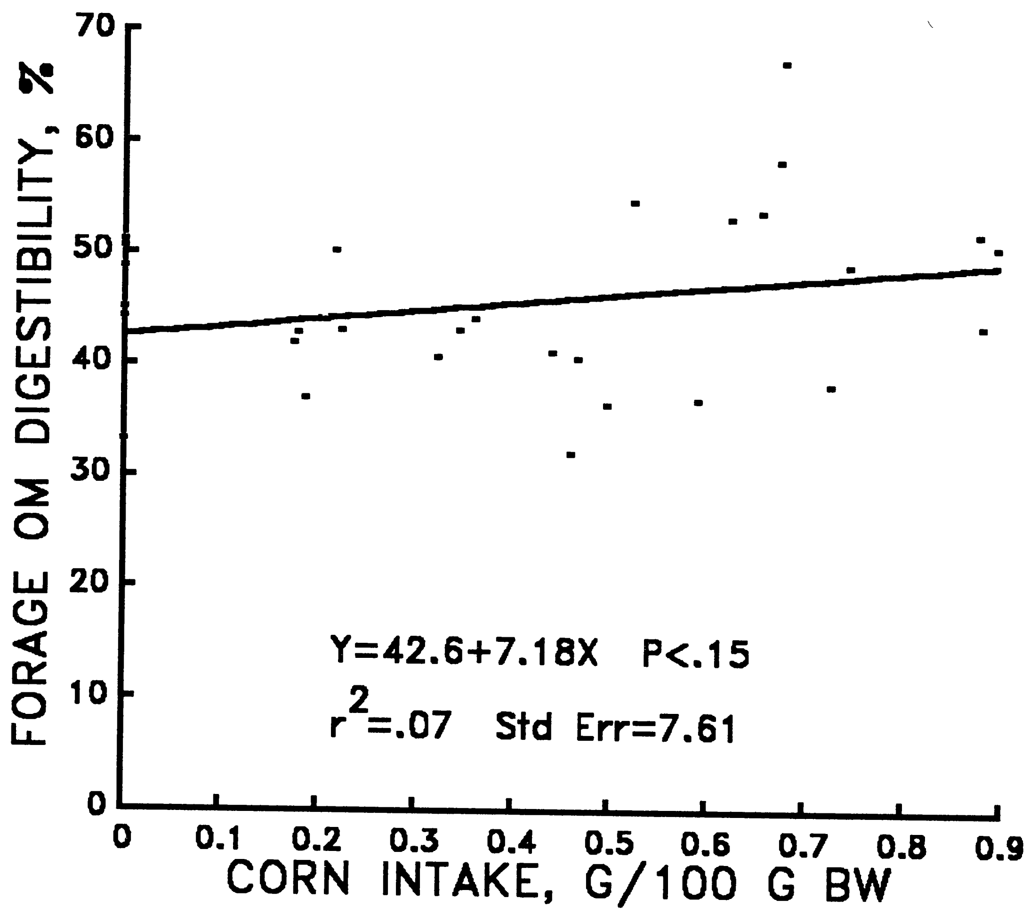


FIGURE 8. REGRESSION RELATIONSHIP BETWEEN CORN SUPPLEMENT INTAKE AND FORAGE DIGESTIBILITY FOR CALVES GRAZING TALLGRASS PRAIRIE IN AUGUST.

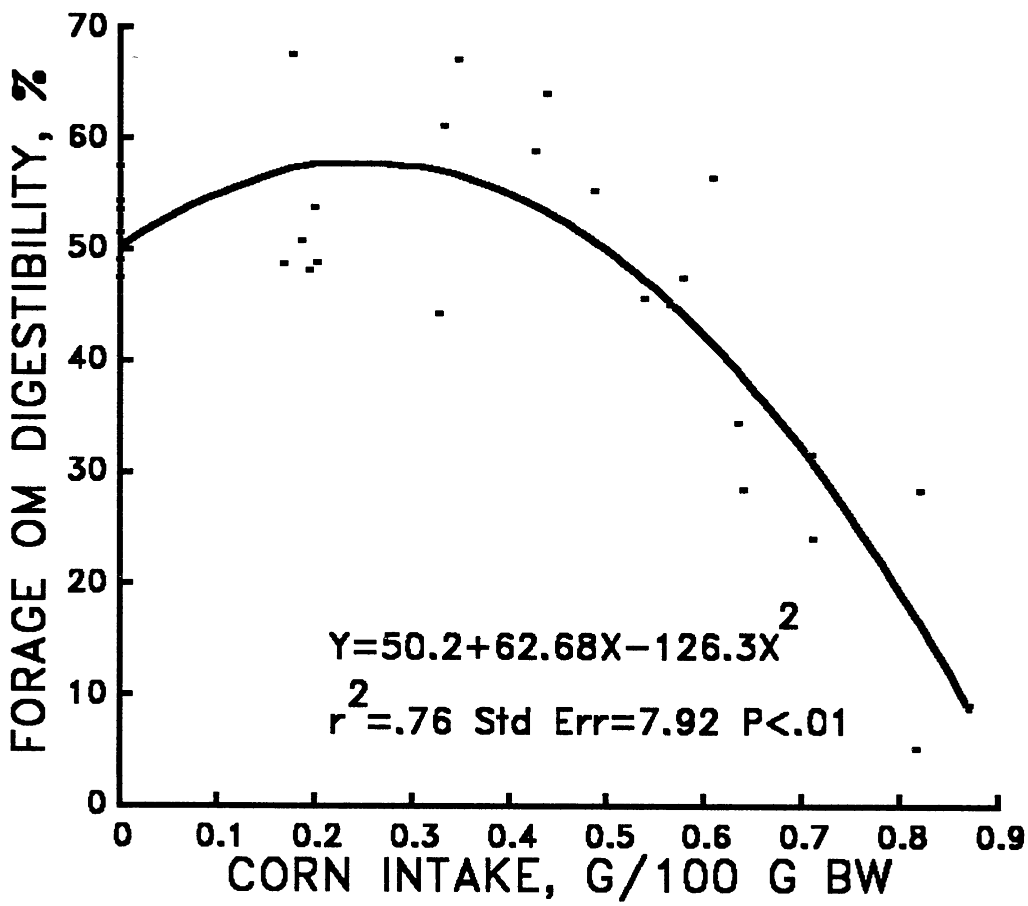


FIGURE 9. REGRESSION RELATIONSHIP BETWEEN CORN SUPPLEMENT INTAKE AND TOTAL DIGESTIBILITY FOR CALVES GRAZING TALLGRASS PRAIRIE IN JUNE.

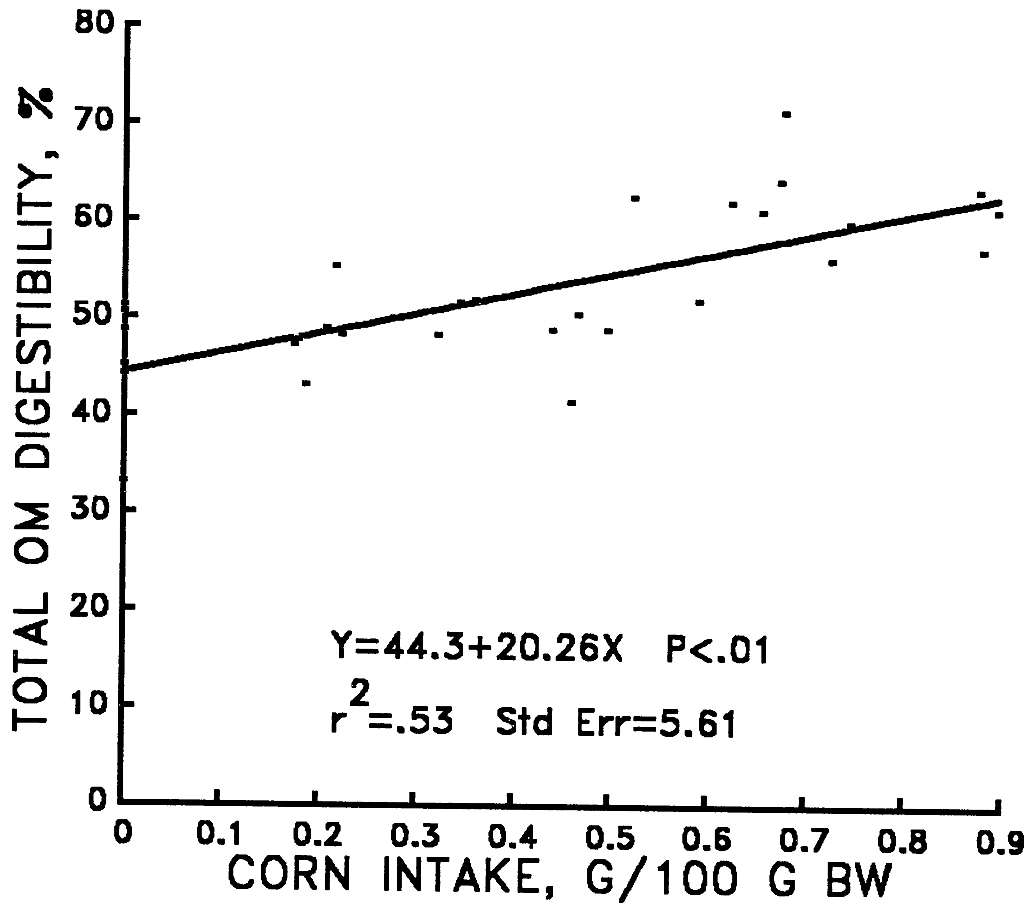
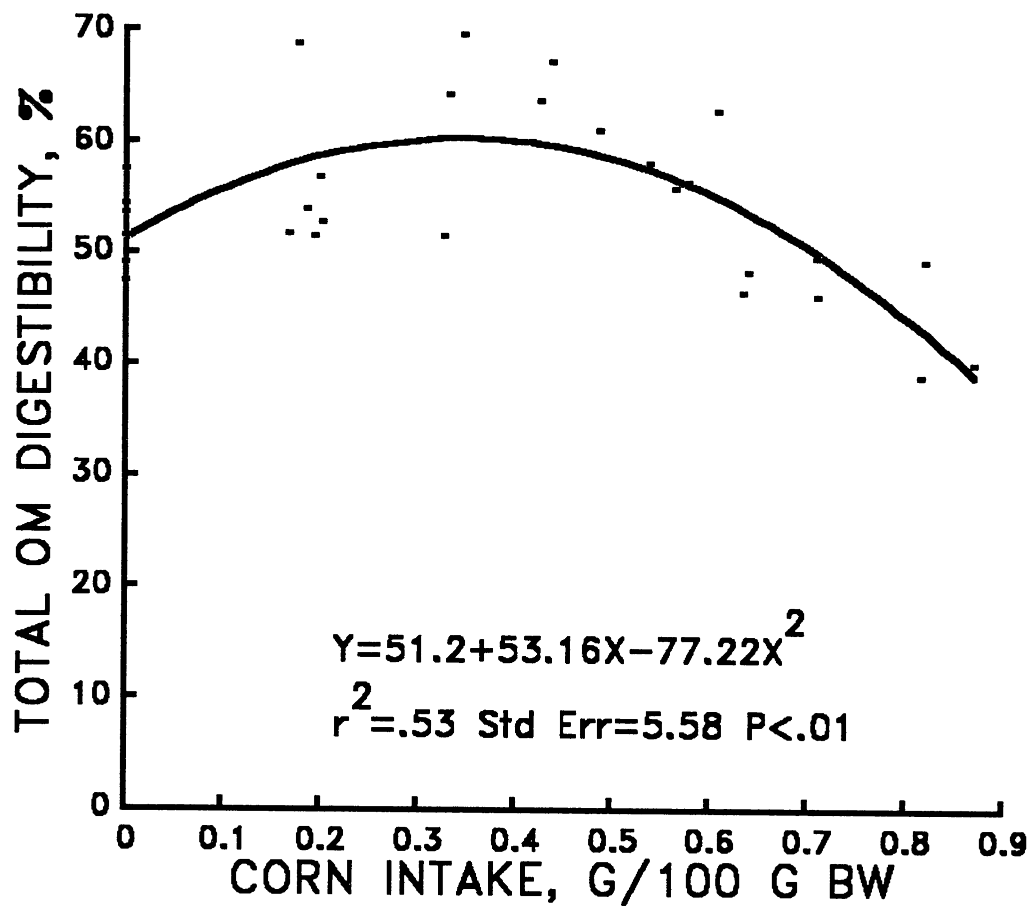


FIGURE 10. REGRESSION RELATIONSHIP BETWEEN CORN SUPPLEMENT INTAKE AND TOTAL DIGESTIBILITY FOR CALVES GRAZING TALLGRASS PRAIRIE IN AUGUST.



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APPENDICES

APPENDIX A

MONTHLY PRECIPITATION (mm) AND TEMPERATURES (C) AT STILLWATER, OKLAHOMA, JANUARY, 1990, THROUGH AUGUST, 1990.

MONTH	PRECIPITATION	DEVIATION	TEMPERATURE	DEVIATION
JANUARY	47.0	24.1	5.2	3.4
FEBRUARY	97.0	66.6	6.2	1.5
MARCH	182.1	126.5	9.6	0.3
APRIL	149.4	83.8	13.8	-1.9
MAY	121.9	-7.1	18.9	1.3
JUNE	25.7	-73.9	27.2	2.2
JULY	36.4	-59.4	26.7	-1.2
AUGUST	91.4	19.6	27.2	-.1

APPENDIX B

FORAGE AVAILABILITY AND HERBAGE ALLOWANCE DURING THE JUNE AND AUGUST SUPPLEMENTATION TRIALS.

ITEM	JUNE	AUGUST
PADDOCK SIZE, ha	8.3	15.8
FORAGE, Kg/ha	1950	1400
DEAD, Kg/ha	740	250
LIVE, Kg/ha	1210	1150
TOTAL FORAGE LIVE, Kg	10010	18190
FORAGE LIVE ALLOWANCE, Kg/d	590	1070
AVERAGE BW/STEER[a], Kg	196	237
FORAGE LIVE ALLOWANCE, Kg/100Kg BW/d	10	15

[a] n=30

APPENDIX C

BODY WEIGHT, FECAL OUTPUT, DIET DIGESTIBILITY AND DAILY INTAKE OF CALVES GRAZING TALLGRASS PRAIRIE AND SUPPLEMENTED WITH DIFFERENT LEVELS OF CORN.

TRIAL	SUPPLEMENT INTAKE, g/100g BW					SE[a]
	0	.2	.4	.6	.8	
JUNE						
BW, Kg	197	197	197	197	195	4.79
INTAKE, Kg/d	3.19	3.16	4.20	4.66	5.24	.34
FECAL OUTPUT, Kg/d	1.73	1.64	2.16	1.86	2.06	.13
TOTAL DOM, %	45.4	48.3	48.6	59.5	60.2	3.16
AUGUST						
BW, Kg	236	239	236	237	237	6.68
INTAKE, Kg/d	4.39	5.27	6.79	5.78	4.90	.61
FECAL OUTPUT, Kg/d	2.10	2.30	2.48	2.49	2.67	.23
TOTAL DOM, %	52.1	55.8	63.1	56.6	45.2	3.50

[a] n=6.

VITA

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